



**Specific models to assess the possible use of
alternative external carbon sources for
nitrogen removal in wastewater treatment.**

By

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A Dissertation

Submitted in fulfilment for the degree of

DOCTOR OF PHILOSOPHY

In

Faculty of Environmental and Information Engineering

University of Technology Sydney

New South Wales, Australia

February 2018

CERTIFICATE OF ORIGINAL AUTHORSHIP

This is to certify that I am responsible for the work in this thesis, and to the best of my knowledge it has not been submitted for a degree or for part of a degree requirement to another institution, unless fully acknowledged in the texts.

I also want to certify that I have written this thesis, with helps and supports as mentioned in the acknowledgements, and to the best of my knowledge, all information sources and literature used are indicated in the thesis accordingly.

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ACKNOWLEDGEMENTS

It is my greatest pleasure here to show my sincere gratitude toward my principal supervisor Prof. Huu Hao Ngo and my co-supervisor Dr. Tien Vinh Nguyen and Dr. Wenshan Guo. As all of them with their vast research knowledge and experience, have provided me with the utter best support since my transfer into UTS. Without their invaluable guidance, it would have not been possible for me to finish my candidature. Especially Prof. Huu Hao Ngo who has worked over time including during trips and weekends to provide me with endless advices and feedbacks, from my thesis structure, my research papers, my report writings skills, down to life and career advices. Furthermore, thanks to his professional, but also humorous personality, it is in my most honest belief that I have become a better researcher and a better person now than back when I first entered his office. And to Dr Tien Vinh Nguyen, who always looked out and provided me with supports whenever I needed, I will also forever be grateful. Last but not least, I also want to thank Dr. Wenshan Guo's extraordinary helps with the revising of my research papers and thesis chapters.

It is hence quite regretful that my time in UTS was quite short, and that I could not learn more from Prof. Huu Hao Ngo, Dr Tien Vinh Nguyen and Dr. Wenshan Guo. But I believe my career definitely will cross path with them in the future and I will continually learn more from their wisdoms.

Besides, I would like to thank Mr Phil Thomas who contributed greatly with the proofreading work of my thesis. Not to mention other staffs and fellow research students from UTS GRS and FEIT, who helped me with the administration works and enhanced my writing skills. Without their helps, I would not be able to produce this thesis with this current quality.

I also want to express thanks to the staffs and fellow students from RMIT who has assisted me greatly with the experimental works. Especially, Jeffry Yulian, who was a good friend, mentor and research partner, who helped me greatly with my experimental works during early days of my candidature.

Finally, I want to expand my gratitude to both of my parents, my siblings, their extended family (especially the nieces), my friends, the UTS Housing staffs, the UTS Kendo club members, and other kenshi. All of them were very considerate to my struggle in study and provided me with their full supports and encouragements throughout my entire PhD study.

Table of Contents

CERTIFICATE OF ORIGINAL AUTHORSHIP	ii
ACKNOWLEDGEMENTS	iii
Table of Contents	iv
Table Tittles	ix
Figure Caption.....	xi
Abbreviations	xiv
PhD Dissertation Abstract	xvi

Chapter 1 - INTRODUCTION

1.1. Research background	1-2
1.2. Research Aim	1-5
1.3. Research Questions	1-5
1.4. Research Scopes	1-6
1.5. Significance of the study	1-7
1.6. Thesis outlines.....	1-9

Chapter 2 - LITERATURE REVIEW

2.1. Introduction to the Activated sludge system	2-2
2.1.1. Microorganisms in the Activated sludge system.....	2-3
2.1.2. Required nutrients for Microorganisms' growth	2-4
2.1.3. Important operational parameters in the Activated Sludge system	2-4
2.2. Denitrification in wastewater treatment.....	2-5
2.3. Denitrification kinetics that corresponds to carbon utilisation.....	2-10
2.4. Denitrification issues regarding internal carbon utilisation.....	2-12
2.5. Studies on external carbon sources in the literature.....	2-16
2.5.1. List of external carbon studies in the literature	2-17
2.5.2. Comparison of carbon sources in the literature	2-22
2.6. Summary.....	2-29

Chapter 3 - EXPERIMENTAL METHODOLOGY

3.1. Definition of model, simulation and system used in this thesis.....	3-2
---	------------

3.2. Experimental Methodology Outline	3-3
3.3. Classifications of methodologies	3-9
3.4. Specific Denitrification Rate (SDNR) Batch tests	3-15
3.4.1. General introduction to SDNR Batch Tests	3-15
3.4.2. SDNR Batch Tests set-up	3-15
3.5. Nitrogen Mass-Balance (NMB) Conceptual Models.....	3-18
3.5.1. General introduction to the NMB model	3-18
3.5.2. NMB models of post-anoxic denitrification	3-19
3.5.3. NMB model of pre-anoxic denitrification.....	3-22
3.6. Mumax Batch tests	3-26
3.6.1. General introduction to Mumax Batch tests.....	3-26
3.6.2. The Mumax Equation	3-27
3.6.3. The Mumax Test Set-up.....	3-33
3.7. Biowin software simulations	3-34
3.7.1. General introduction to Biowin.....	3-34
3.7.2. Biowin in regarding to external carbon simulation.....	3-35
3.8. Sequencing Batch Reactors (SBRs).....	3-37
3.8.1. General Introduction to SBR.....	3-37
3.8.2. Lab-scale SBRs parameters used in the literature.....	3-39
3.8.3. The chosen SBRs set-up.....	3-44
3.8.4. The SBRs' performance in controlled conditions	3-48
3.9. The pilot plant	3-57
3.9.1. Introduction to the pilot plant.....	3-57
3.9.2. Pilot plant set-up	3-57
3.9.3. Pilot plant influent characteristics and treatment performance	3-59
3.10. Fermentation batch test	3-61
3.10.1. General Introduction to the fermentation batch tests	3-61
3.10.2. Fermentation Batch Tests set-up.....	3-63
3.11. Chapter summary.....	3-66

Chapter 4 - SUCROSE AS AN ALTERNATIVE EXTERNAL CARBON SOURCE

4.1	Introduction	4-2
4.2	Materials and Methods	4-6
4.2.1	Chemicals and Inoculums	4-6
4.2.2	Denitrifying biomass.....	4-6
4.2.3	Analytical Method	4-6
4.3	Experimental set-up	4-8
4.3.1	Sequencing Batch Reactors (SBRs)	4-8
4.3.2	SDNR test and NMB model.....	4-10
4.3.3	Mumax Batch test and Biowin model	4-13
4.3.4	Pilot-scale plant	4-15
4.4	Results and discussion	4-16
4.4.1	Results from SDNR Tests	4-16
4.4.2	NMB models (based from SDNRs tests) compared to SBRs and pilot plant	4-19
4.4.3	Mumax Batch Tests	4-31
4.4.4	Biowin simulation (based on Mumax tests) compared to SBRs and pilot plant.	4-36
4.4.5	SDNR calculated from Mumax Batch tests compared to SDNR batch tests	4-36
4.5	Conclusion.....	4-41

Chapter 5 - FERMENTED SLUDGE GENERATION AND PRE-ASSESSMENT

5.1	Introduction	5-2
5.2	Materials and Methods	5-4
5.2.1	Chemicals and Inoculums	5-4
5.2.2	Analytical Method	5-5
5.2.3	Experimental set-up	5-5
5.3	Results and Discussion.....	5-7
5.3.1	Experimental results.....	5-7

5.3.2	Results discussion	5-11
5.3.3	Ammonia stripping and struvite formation as forms of ammonia removal 5-16	
5.4	Conclusions	5-21

Chapter 6 - FERMENTED SLUDGE AS ALTERNATIVE EXTERNAL CARBON SOURCE

6.1	Introduction	6-2
6.2	Materials and Methods.....	6-4
6.2.1	Methodology	6-4
6.2.2	Chemicals and Inoculums	6-5
6.2.3	Denitrifying biomass.....	6-5
6.2.4	Analytical Method	6-6
6.3	Experimental set-up.....	6-7
6.3.1	Fermentation Sludge Generation	6-7
6.3.2	Sequencing Batch Reactors SBRs.....	6-8
6.3.3	SDNR test and NMB model.....	6-9
6.3.4	Mumax Batch test and Biowin model	6-11
6.4	Results and Discussions.....	6-13
6.4.1	Characteristics of Tested Fermented Sludge.....	6-13
6.4.2	Results from SDNR Tests	6-16
6.4.3	Mumax Batch Tests	6-20
6.4.4	The SBRs results.....	6-25
6.4.5	Post-anoxic denitrification simulation: NMB model vs SBRs	6-25
6.4.6	Post-anoxic denitrification simulation: Biowin model vs SBRs ...	6-29
6.4.7	Pre-anoxic denitrification simulation: Biowin vs NMB model.....	6-36
6.4.8	SDNR calculation: Mumax vs SDNR batch tests	6-42
6.4.9	Results summary	6-46
6.5	Conclusion	6-48

Chapter 7- OVERVIEW OF ALL MODELS

7.1.	Technical advantages and disadvantages of each model.....	7-2
-------------	--	------------

7.2. Time and Resources required to operate each model.....	7-6
Chapter 8 - CONCLUSIONS AND RECOMMENDATIONS	
8.1 Conclusions	8-2
8.2 Recommendations.....	8-3
REFERENCES	R-2
APPENDICES	
Appendix I – Mathematica’s Syntax sample for Mumax experiment analysis	A-2
Appendix II – R Statistics analysis for Chapter 4 SDNR tests	A-3
Appendix III – R Statistics analysis for Chapter 6 SDNR tests	A-8
Appendix IV - SBR feed Selection.....	A-12
Appendix V – Time-consumption for each model testing	A-16
Appendix VI – NMB model of a post-anoxic denitrification	A-18
Appendix VII – NMB model of a pre-anoxic denitrification.....	A-22
Appendix VIII – Pre-anoxic denitrification Biowin simulation scenarios.....	A-26
Appendix IX – Post-anoxic denitrification Biowin simulation scenarios	A-29
Appendix X – Biowin simulation scenarios.....	A-30

Table Tittles

Chapter 2

Table 2.1: SDNR comparison at 20°C.....	2-23
Table 2.2: The denitrification kinetics of MicroC [™] , acetate and methanol (adapted from Cherchi et al., 2009).	2-24
Table 2.3: The short-term response of each specific carbon acclimated biomass when using other carbon sources (adapted from Cherchi et al.,2009).	2-25

Chapter 3

Table 3.1: All of the main methods used in the thesis as classified under modelling classification according to Henze (2008).....	3-12
Table 3.2: Fermentation batch test as classified under modelling classification.....	3-14
Table 3.3: Generation, Accumulation and Consumption of Nitrogen-based matter in wastewater	3-20
Table 3.4: Equations showing concentration of nitrate and ammonia for each stage in pre-anoxic denitrification.....	3-24
Table Table 3.5: Mumax batch tests symbols and units	3-28
Table 3.6: Effect of multiple anoxic and aerobic stages on COD and NH ₄ removal.	3-41
Table 3.7: The synthetic wastewater parameters.....	3-46
Table 3.8: The performance of all SBRs in stable conditions.	3-55

Chapter 4

Table 4.1 Synthetic wastewater characteristics.	4-8
Table 4.2 SDNR of sucrose and sucrose + wastewater mixtures	4-18
Table 4.3 The measured COD of the SBRs.....	4-24
Table 4.4 The measured NO ₃ of the SBRs.....	4-24
Table 4.5 Comparison of the results from NMB models and SBR.....	4-24
Table 4.6 Nitrogen Mass Balance Model of the pilot plant.....	4-27
Table 4.7 Denitrification rate based on NMB models	4-29
Table 4.8 Comparison of the results from NMB models and pilot plant.....	4-30
Table 4.9: Growth yield (Y _H) and growth rate value (μ _S) retrieved from the Mumax batch tests	4-32
Table 4.10 Consumed C: N to produce energies and by-products resulting from denitrification activities (excluding cell growth).....	4-34
Table 4.11: Comparison of the results from SBRs and Biowin simulations	4-37
Table 4.12: Pilot plant effluent results compared to Biowin simulations.....	4-38

Chapter 5

Table 5.1 The full set of data for all experiments.	5-9
--	-----

Table 5.2: Advantages and disadvantages of Ammonia stripping and Struvite formation	5-19
---	------

Chapter 6

Table 6.1: The full set of data for all fermentation experiments.	6-14
Table 6.2: Ammonia removal using ammonia stripping	6-15
Table 6.3: The SDNR results concerning the two fermented and dark fermented biosolids.....	6-19
Table 6.4: Results from the Mathematica analysis	6-22
Table 6.5: Growth yield (YH) and growth rate value (μ S) retrieved from the Mumax batch tests.....	6-22
Table 6.6: Carbon used by denitrifiers based on Mumax batch test results	6-23
Table 6.7: Summary of the SBRs results.....	6-24
Table 6.8: Results from the NMB model compared to SBR results.....	6-27
Table 6.9: The effluent NO_3 and TN based on Biowin simulation of the pilot plant compared to the SBRs results.....	6-31
Table 6.10: The effluent NO_3 and TN of Scenarios fb1 and fb2	6-35
Table 6.11: Denitrification rate based on the NMB model	6-38
Table 6.12: Nitrogen Mass Balance Model for the pilot plant	6-39
Table 6.13: SDNR calculated from the Mumax batch tests	6-44
Table 6.14: Comparison between different physical and mathematical models	6-47

Chapter 7

Table 7.1: The strategies employed in the thesis and their classification	7-3
---	-----

Figure Caption

Chapter 1

Figure 1.1: The Thesis outline.....	1-9
-------------------------------------	-----

Chapter 2

Figure 2.1: Organic carbon consumption in the biological nutrient removal process (adapted from Jang et al. 2004).	2-7
Figure 2.2: Simultaneous Nitrification-Denitrification (adapted from Wrage et al. 2001).	2-9
Figure 2.3: Typical post-anoxic denitrification set-up.	2-12
Figure 2.4: Typical pre-anoxic denitrification set-up.....	2-14
Figure 2.5: Effect of incomplete denitrification on a system SVI (adapted from Chen et al. 2010).	2-15
Figure 2.6: Global methanol price from 2001 to 2015, according to Methanex.....	2-18
Figure 2.7: SDNR of methanol, ethanol and acetate at different temperatures (adapted from Dold et al.,2008).	2-26
Figure 2.8: SDNR and carbon consumption rate of methanol, ethanol and acetate at different temperatures (adapted from Peng et al., (2007)	2-27
Figure 2.9: Effluent nitrate concentration of explosion wastewater using glucose, sodium acetate, methanol as external carbon sources (adapted from Shen et al.,2009).	2-28

Chapter 3

Figure 3.1: Standard mathematical modelling or computer simulation methodology.....	3-4
Figure 3.2: Initial thesis structure flowchart.	3-5
Figure 3.3 Relationships between different simulation models used in this thesis.	3-8
Figure 3.4: <i>One of the SDNR batch tests</i>	3-17
Figure 3.5: A typical post-anoxic denitrification system	3-19
Figure 3.6: A basic pre-anoxic denitrification set-up.....	3-23
Figure 3.7: Relationship between Y_h (growth yield) and COD consumed	3-29
Figure 3.8: The characterisation of influent wastewater for Biowin simulation in this experiment.....	3-36
Figure 3.9: The default pilot plant diagram used in this thesis.	3-37
Figure 3.10: Four SBRs set-ups	3-44
Figure 3.11: Breakdown of a SBR cycle	3-45

Figure 3.12: Soluble COD of the four SBRs before the start of the anoxic period.	3-48
Figure 3.13: Soluble COD of the four SBRs after the start of the anoxic period / before being discharged.	3-49
Figure 3.14: Ammonia concentration of the four SBRs before the start of the anoxic period.	3-50
Figure 3.15: Ammonia concentration of the four SBRs after the start of the anoxic zones/ before being discharged.	3-50
Figure 3.16: Nitrate concentration of the four SBRs before the start of the anoxic zones.	3-51
Figure 3.17: Nitrate concentration of the four SBRs after the start of the anoxic zones/ before being discharged.	3-52
The data in the red circle (Figure 3.18, showing nitrate concentration in Reactor B and Reactor D after the anoxic zone) was affected by adding sucrose as an external carbon source. More details are reported in section 4.4.1.	3-53
Figure 3.19: MLSS concentration of the four SBRs.	3-53
Figure 3.20: The sludge bed and SVI of the four SBRs.	3-54
Figure 3.21: The SOUR of the SBRs.	3-55
Figure 3.22: Diagram of the pilot plant	3-58
Figure 3.23: Photograph of the pilot plant (Yulian 2014).	3-59
Figure 3.24: COD profile of influent and effluent of the pilot plant.	3-60
Figure 3.25: N profile of influent and effluent of the pilot plant.	3-61

Chapter 4

Figure 4.1 The relationships between different simulation models used in this chapter.	4-4
Figure 4.2 Basic diagram of a SBR.	4-9
Figure 4.3 The Mumax batch test set up.	4-14
Figure 4.4 Schematic diagram of the pilot plant.	4-16
Figure 4.5 Nitrate concentration before and after anoxic zone in Control Reactor (A and C).	4-21
Figure 4.6 Nitrate concentration before and after anoxic zone in Tested Reactors (B and D).	4-22
Figure 4.7: Diagram of the pilot plant based on NMB calculations	4-29
Figure 4.8 Biowin simulation versus actual data from pilot plant.	4-39
Figure 4.9 SDNR calculated from Mumax tests vs SDNR tests	4-40

Chapter 5

Figure 5.1 The C:N ratio of tested fermented biosolids (Experiments 4 and 7)	5-11
Figure 5.2 VA/rbCOD ratio of the different fermentation set-up	5-12
Figure 5.3 rbCOD of the different feed substrates	5-14
Figure 5.4 Change in rbCOD due to adding sucrose	5-14
Figure 5.5: Flowchart diagram of Struvite formation set-up	5-17
Figure 5.6: Flowchart diagram of Ammonia stripping set-up	5-18
Figure 5.7. The Ammonia removal rate of different set ups	5-21

Chapter 6

Figure 6.1: The relationships between different simulation models used in this chapter	6-4
Figure 6.2: The Mumax batch test set up	6-13
Figure 6.3 Ammonia stripping performance as pre-treatment to fix the fermented biosolids C:N ratio	6-16
Figure 6.4: Nitrate profile of the two sets of SDNR batch test (including duplicates)	6-17
Figure 6.5: The first Mumax batch test performance	6-20
Figure 6.6: The second Mumax batch test performance	6-21
Figure 6.7: The effluent characteristics of the control and tested SBRs	6-28
Figure 6.8: The effluent nitrate from Biowin simulation of the pilot plant (control stage versus after added fermented sludge)	6-29
Figure 6.9: The effluent TN from Biowin simulation of the pilot plant (control stage versus after added fermented sludge)	6-30
Figure 6.10: The effluent COD from Biowin simulation of the pilot plant (control stage versus after added fermented sludge)	6-32
Figure 6.11: The system MLVSS from Biowin simulation of the pilot plant (control stage versus after added fermented sludge)	6-33
Figure 6.12: the effluent nitrate from Biowin simulation of Scenario fb1 and fb2.	6-34
Figure 6.13: The effluent TN from Biowin simulation of Scenario fb1 and fb2	6-34
Figure 6.14: The effluent nitrate from Biowin simulation of Scenarios d1 and d2	6-36
Figure 6.15: The effluent TN from Biowin simulation of Scenarios d1 and d2	6-37
Figure 6.16: The pilot-plant diagram based on NMB calculation	6-41
Figure 6.17: The pilot-plant diagram based on NMB calculation	6-41
Figure 6.18: SDNR calculated from the Mumax batch tests	6-43
Figure 6.19: SDNR of the tested fermented sludge samples using various methodologies	6-45

Chapter 7

Figure 7.1 Amount of time required to run each tested model.....	7-6
Figure 7.2 Number of samples needed to run each test.....	7-7
Figure 7.3 Amount of time lost if an issue occurs.	7-8

Abbreviations

Symbol	Description
bCOD	Biodegradable COD
BOD	Biological Oxygen Demand
C:N	Carbon: Nitrogen Ratio
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
F/M	Food/ Microorganism Ratio
GAOs	Glycogen-Accumulating Organisms
HRT	Hydraulic Retention Time
IR	Internal Recycle/ Internal Return
MLE	Modified Luzack-Ettinger
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
NMB	Nitrogen Mass Balance
OUR	Oxygen Uptake Rate
PAOs	Phosphate-Accumulating Organisms
PHA	Polyhydroxyalkanoate
PHB	Polyhydroxybutyrate
rbCOD	Readily Biodegradable Chemical Oxygen Demand
sbCOD	Slowly Biodegradable Chemical Oxygen Demand
SBRs	Sequence Batch Reactors
SDNR	Specific Denitrification Rate
SDNR (t°C)	Specific Denitrification Rate at T°C
SE	Significant Error
SOUR	Soluble Oxygen Uptake Rate
SRT	Sludge Retention Time
SS	Suspended Solids
SVI	Sludge Volume Index

TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solids
VA	Volatile Acid
VFA	Volatile Fatty Acid
VSS	Volatile Suspended Solids
WAS	Wasted Activated Sludge
WWTP	Wastewater Treatment Plant

PhD Dissertation Abstract

Author: Duc Anh Phung
Date: 1st May 2018
Thesis title: Specific models to assess the possible use of alternative external carbon sources for nitrogen removal in wastewater treatment.
Faculty: Environmental and Information Technology
School: Civil and Environmental Engineering
Supervisors Prof. Huu Hao Ngo (Principal Supervisor)
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Abstract

Achieving effective denitrification in municipal wastewater treatment is amongst one of the world's biggest environmental challenges to sustainability. The problem is specifically due to the slow denitrification rate in the anoxic zone, which is caused by the lack of readily biodegradable organic carbon. Without effective treatment, the excessive discharge of nitrogen into waterways can cause eutrophication, deterioration of water sources and danger to human health. Various solutions including the construction, expansion and modification of existing wastewater treatment plants (WWTPs) to meet the increasing demand, however, often require the whole treatment plant being redesigned, with high investment cost, more operating expenses, and retraining of existing staffs.

An alternative strategy is adding an external carbon source directly into the anoxic zone. The advantage of this option is: (i) it is easy to implement, (ii) it requires little modification to an existing WWTP (so high costs and treatment plant operations will not be overly affected), and (iii) it can meet both the short-term and long-term treatment standards. The search for a material that is readily

degradable, inexpensive, and preferably to be either a waste material or by-product with favourable C:N ratio from local industries, has been ongoing in the last few decades, and is also the central theme of this research.

The original contribution this research makes to our knowledge of the topic is done by simulating the potential of industrial-grade sucrose and fermented biosolids. These are two less well-studied carbon subgroups that can act as external carbon sources for improving denitrification in municipal wastewater treatment. This task was specifically achieved by establishing a systematic cross-verification of various mathematical, conceptual and physical models, which will not only provide more information about the two carbon subgroups, but also help to identify various flaws and disadvantages each model may carry. Despite both sucrose and various other fermented sludge types being experimented upon in this thesis, the real original research subjects of this study are the fermented and dark fermented biosolids, two substances within fermented sludge subgroup. They were selected based on the results of a series of fermentation batch tests.

Meanwhile the reason why industrial-grade sucrose was also studied despite it not being necessarily new is, firstly, due to sucrose's insignificant nitrogen content, consistency and uniform characteristics; this makes it the perfect subject to test and develop the cross-verification methodology. Secondly and in reference to future research on this topic, sucrose is the product of cellulose hydrolysis, which has very similar optimal operation conditions (in terms of pH and temperature) with sludge fermentation. This indicates the future potential for utilising cellulose hydrolysis in the same sludge fermenter to improve and optimise fermented sludge generation.

The results indicated that while sucrose could be used to improve the denitrification process and treat several treatment scenarios down to below standard, fermented and dark fermented biosolids however, provide a much

better treatment performance, and complete denitrification in almost all simulations. In fact, its maximum potential is exceptional that within the scope of this study, it was only limited by the treatment demand rather anything else.

The results also found that the NMB models and cross-verification methodology being established by the candidate were very successful in simulating the effects of adding sucrose and fermented biosolids on denitrification improvement. It is however recommended to apply these models and methodology into future external carbon source study, not only to detect their flaws and drawbacks, but also to improve them accordingly.

Keywords: Sucrose, fermented sludge, external carbon source, modelling cross-verification, cellulose hydrolysis.